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ORIGINAL ARTICLE

Discovery of Female *Laudakia papenfussi* Zhao, 1998, with Insights into its Phylogenetic Relationships

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Abstract The sole voucher of Papenfuss' Rock Agama, *Laudakia papenfussi* (CIB 775001), an adult male, was collected from Zanda, Tibet, China on July 1, 1976 and described in 1998. No information on this species appeared since its description. In September 2014, we collected one female and six males at the type locality. Based on the original description and these newly collected specimens, we re-describe this species. Principal components analysis based on 33 morphological characteristics clearly diagnose *L. papenfussi* from closely related species. One way ANOVA test shows significant differences among four Tibetan rock agamas for 9 characters at 95% significant level, and 8 characters at 99% significant level. Molecular analyses recover three main clades in *Laudakia*. The four Tibetan rock agamas place into two geographical groups: Yarlung Zangbo group (*L. sacra* and *L. wui*) and the Himalayan group (*L. tuberculata* and *L. papenfussi*).

Keywords Papenfuss' Rock Agama, Tibetan Plateau, morphology, phylogeny

1. Introduction

The genus *Laudakia* Gray, 1845 (Agamidae Gray, 1827) contains 20 species with a checkered taxonomic history dating back to more than 250 years, when the first member of this group, *Lacerta stellio* Linnaeus, 1758 was described (Baig *et al.*, 2012). *Laudakia* ranges from Greece and the Nile River delta in the west through the Middle East and Central Asia to Gobi Altai in the north-east and the Yarlung Zangbo in the east (Ananjeva and Tuniev, 1994). Generally, they are saxicolous and live in either natural (rocks, screes, and clay slopes) or artificial (stone walls, bridge parapets, ancient buildings) environments in arid zones.

Tibet hosts four species of rock agamas all of which are endemic to Qing Zang Gaoyuan (the valid name of the US Board on Geographic Names for the variant name Tibetan Plateau): *L. sacra* (Smith, 1935), *L. wui* Zhao, 1998, *L. tuberculata* (Gray, 1827), and *L. papenfussi* Zhao, 1998. Ananjeva *et al.* (1990) elevated *Agama himalayana sacra* to a full species and assigned it to *Laudakia* as *L. sacra*. Zhao (1998a) described the new species *L. wui*. The sole voucher of *L. papenfussi* (adult male CIB 775001) was collected on 1 July 1976 from Zanda, Xizang (Tibet), China and was also described by Zhao (1998b). Since then, no information about this species appeared. Bahuguna (2008) documented elevational variation in morphology of *L. tuberculata* in the western Himalayas.

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To better understand the diversity of *Laudakia* in Tibet, we conducted herpetofaunal investigations there from 2012 to 2014. Thirty-two specimens of four known species of rock agama were collected (Figure 1). Fortunately, one female and six male Papenfuss' Rock Agamas were sampled in September 2014 at its type locality (Figure 2). Because the species was described from a single specimen, nothing is known about variation within it. Here, we re-describe *L. papenfussi* based on its original description and our examination of the newly collected specimens. We employ principal component analyses (PCA) of 33 morphological characters to evaluate their differentiation. To quantify the variations among four species, we performed Analysis of Variance (ANOVA) and post-hoc test for each morphometric character. We also inferred their matrilineal relationships using mitochondrial DNA (mtDNA).

2. Materials and Methods

2.1 Sampling A total of 31 rock agamas were collected. After euthanization and biopsies of tissues, all specimens were fixed in 10% formalin before final preservation in 70–80% EtOH. The Kunming Institute of Zoology

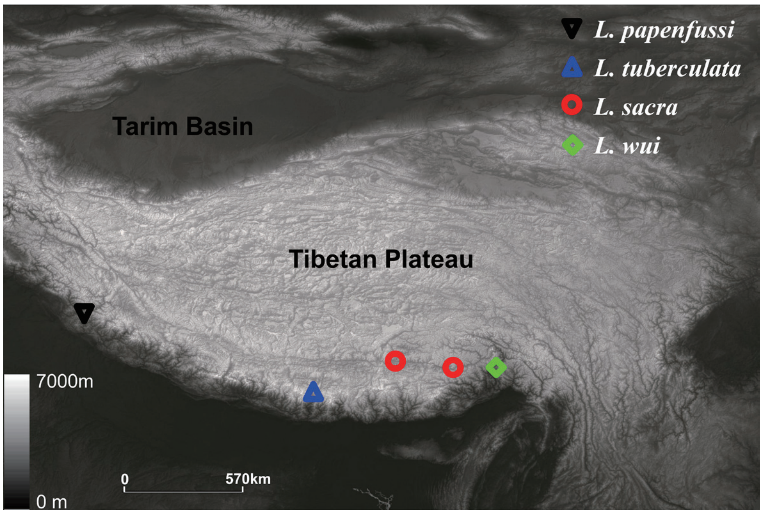

Figure 1 Sampling sites. *Laudakia papenfussi*: Zanda; *L. tuberculata*: Gyirong; *L. sacra*: Mainling, Qüxü; *L. wui*: Mêdog.

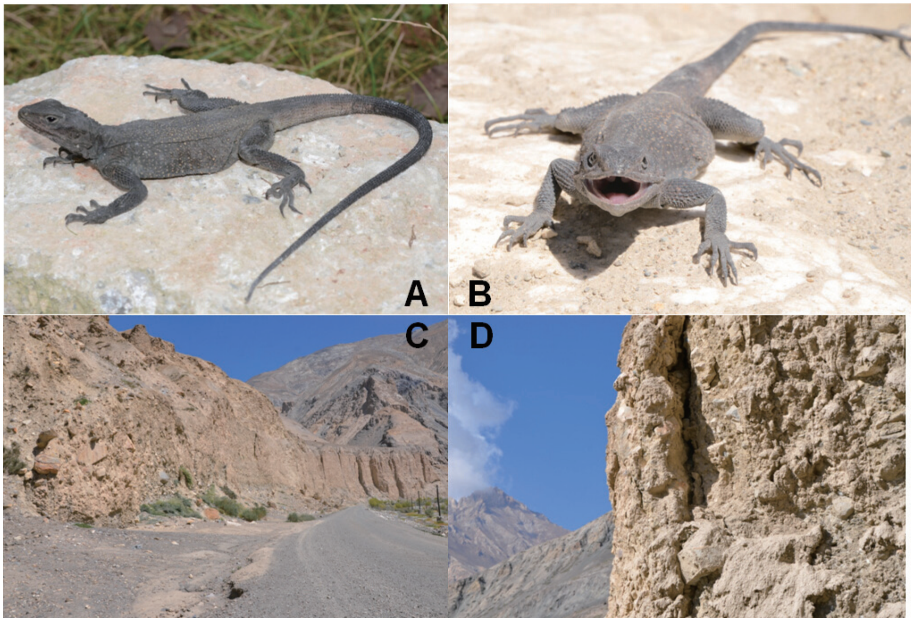

Figure 2 General views in life (A, B) and habitat (C, D) of a female *Laudakia papenfussi*. Photos by Diancheng YANG (Huangshan University).

Animal Care and Ethics Committee approved all work with the animals. All voucher specimens were deposited in Kunming Institute of Zoology, Chinese Academy of Sciences.

2.2 Morphometrics Terminology for the morphological description followed Ananjeva *et al.* (2011) and Baig (2012). Measurements and pholidosis, and their abbreviations were as follows: SVL (snout-vent length); TL (tail length, from vent to the tip of the tail); TRL (trunk length, distance from axilla to groin); LS (shoulder length); HL (distance from snout to posterior edge of tympanum); HW (maximum head width); HD (maximum head height); SL (snout length); ED (horizontal eye diameter); TD (tympanum diameter); IND (internarial distance); IOD (interorbital distance); UEW (upper eyelid width); EED (distance from anterior edge of ear opening to posterior corner of eye); EN (distance from anterior corner of eye to nostril); RW (rostral width); RH (rostral height); MW (mental width); MH (mental height); FL (total length of forelimb); LAL (lower-arm length); HAL (hand length, from proximal end of outer palmar tubercle to tip of the third finger); FEL (femur length); TIL (tibia length); FTL (length of foot and tarsus); NSF (number of subdigital lamellae on third finger); NST (number of subdigital lamellae on fourth toe); NSL (number of supralabials); NIL (number of infralabials); SBR (number of scales bordering the rostral scale); NSN (number of supranasals); SBM (number of scales bordering the mental scale); SBN (number of scales between the nasals); SBO (number of scales between the orbits); RV (rows of vertebral scales); NM (total number of scales around mid-body); NV (number of midventral scales from the posterior edge of the gular region to vent). All measurements were carried out by one person using dial calipers with a precision of 0.01 mm. PCAs of these morphological data were conducted. To eliminate potential effects of age, all measurements were standardized by dividing them by SVL. To compare the variations for all attributes among four species, we carried out one way ANOVA test. Data were firstly tested for normality (using Kolmogorov-Smirnov Test) and homogeneity (using Levene's test) to meet the assumptions of following ANOVA analysis. Post Hoc Multiple Comparisons were conducted by LSD or Dunnett T3 at 95% level of probability. All analysis above mentioned were conducted in SPSS v13.0 (SPSS, Inc., Chicago, IL, USA).

2.3 DNA extraction, amplification and sequencing Total DNA was extracted using standard phenol-chloroform protocols (Sambrook *et al.*, 1989). Fragments of mtDNA gene encoding NADH dehydrogenase subunit 4 (*ND4*) and cytochrome c oxidase I (*CO1*) were amplified with primers ND4/Leu (for *ND4*; Arévalo *et al.*, 1994) and Chmf4/Chmr4 (for *CO1*; Che *et al.*, 2012). Polymerase chain reaction (PCR) mixtures (25 μL) contained 18.5μL ddH$_2$O, 1μL (60 ng/μL) genomic DNA, 2.5μL buffer, 1μL of each primer, and 1μL Taq DNA polymerase. PCR was performed on a DNA Engine Dyad Cycler as follows: 5 min of initial denaturation at 95 °C, 35 cycles of denaturation for 1 min at 94 °C, annealing for 1 min at 45 °C for *CO1* and 50 °C for *ND4*, and a final extension at 72 °C for 1 min. PCR products were purified and then sequenced in both directions with BigDye Terminator Cycle Sequencing Kit and ABI PRISM 3730 (Applied Biosystems). All sequences were deposited in GenBank (Table 1).

2.4 Phylogenetic analyses Sequences of *CO1* and *ND4* from a closely related outgroup genus *Phrynocephalus* were downloaded from GenBank (Table 1). We also retrieved *CO1* and *ND4* sequences of other species of *Laudakia* from GenBank (Table 1). DNA sequences were aligned with CLUSTAL X v1.81 (Thompson *et al.*, 1997) and optimized with BioEdit ver. 7.1.9 (Hall, 1999). Before reconstructing the genealogy, we selected the best-fit model of sequence evolution using JModelTest v2.1.1 (Darriba *et al.*, 2012) with Akaike Information Criterion (AIC). Bayesian analysis was performed using MrBayes v3.2.1 (Ronquist and Huelsenbeck, 2003) with default priors and the appropriate model. We ran ten million generations of MCMC simulations with four separate chains (three heated, one cold) with a sample frequency of 1000 generations, and the first 25% of the trees were discarded as burn-in. For more confidence, ML analyses with nonparametric bootstrap nodal support were performed using an internet implementation of RAxML v7.2.3 (Stamatakis *et al.*, 2008).

3. Results and Discussion

3.1 Redescription of *Laudakia papenfussi* Zhao, 1998 Below, we redescribe our newly collected specimens and provide photographs of living individuals (Figures 3–4), as well as their habitat and microhabitat. Further, we present information on its distribution, ecology and conservation status.

Diagnosis Head and body depressed; dorsal and lateral surface scattered with yellow spots of equal size of vertebral scales; vertebral scales oblique towards mid-line and anterior; enlarged mucronate scales scattered

Table 1 Details of the individuals analyzed in molecular analysis, with localities and GenBank accession numbers. KIZ=Kunming Institute Zoology.

	Voucher No.	Locality	GenBank accession No.	
			CO1	ND4
Ingroup				
L. sacra	KIZ015052	Mainling, Nyingtri, Tibet, China	KU926280	KU926294
	KIZ015054	Mainling, Nyingtri, Tibet, China	KU926279	KU926293
	KIZ015207	Qüxü, Lhasa, Tibet, China	KU926281	KU926295
	KIZ015202	Qüxü, Lhasa, Tibet, China	KU926282	KU926296
	KIZ015199	Qüxü, Lhasa, Tibet, China	KU926283	KU926297
L. wui	KIZ06668	Medog, Nyingtri, Tibet, China	KU926277	KU926291
	KIZ011017	Medog, Nyingtri, Tibet, China	KU926278	KU926292
	KIZ06670	Medog, Nyingtri, Tibet, China	KU926276	KU926290
L. papenfussi	KIZ048669	Zanda, Ngari, Tibet, China	KU926275	KU926289
	KIZ048670	Zanda, Ngari, Tibet, China	KU926274	KU926288
	KIZ048664	Zanda, Ngari, Tibet, China	KU926284	KU926298
L. tuberculata	KIZ012554	Gyirong , Shigatse, Tibet, China	KU926271	KU926285
	KIZ012555	Gyirong, Shigatse, Tibet, China	KU926272	KU926286
	KIZ012556	Gyirong, Shigatse, Tibet, China	KU926273	KU926287
L. stellio	ZMMU R-11324	No information	KF691700	KF691669
L. caucasia	KF691701	No information	KF691701	AY053998
L. stoliczkana	HZNU_LS2010001	Yanqi, Bayingol, Xinjiang, China		KC551300
L. lehmanni	ZMMU R-12248	No information	KF691702	KF691670
L. nupta	ZMMU R-12711	No information		KF691667
L. microlepis	R-098	No information	KF691703	KF691699
Outgroup				
P. helioscopus	HZNULS2010001	Yanqi, Bayingol, Xinjiang, China	NC025639	NC025639
P. versicolor		Mazandaran Province, Iran	NC024654	NC024654
P. theobaldi		No information	KJ551842	KJ551842

To avoid private or commercial sampling, the coordinates are not given, if needed, please contact the authors.

on the sides of body; dorsolateral fold present; gular pouch absent; chest and belly black mottled by orange; transverse mid-body scales more than 190; distinct tail segment of four whorls above becoming three below.

Redescription Habitus thin and depressed, head depressed and slightly triangular, HL 28.82±1.70 mm, HW 26.28±3.17 mm, HD 13.76±1.78 mm; SL 4.08±0.32 mm; nasal and nostril elliptic, nostril situated in the center of nasal, directed outwards and posteriorly, on canthus rostralis; 1 or 2 supranasals (KIZ017854 with 2 right supranasals); eye small with a rounded pupil and brown iris; eyelids covered with scales; a row of large and keeled scales arranged in a curve below the lower eyelid, separated from supralabials by 4 rows of small, smooth, slightly bulged scales; tympanum slightly rounded, and naked, more than half of eye diameter (except for juveniles), columella auris visible; tympanum surrounded by irregular conic scales, patches of these scales also on lateral side of neck; scales between eye and tympanum large and keeled on upper part, small and keeled on anterior lower part, granular on posterior lower part; rostral scale broad and low, upper margin straight; SBR 9–11; scales on dorsal head heterogeneous, large on snout, slightly large, bulging and smooth on fronto-parietal region, small on supraocular region, distinctly keeled on occupit; parietal eye an indistinct small white spot. Superciliary ridge poorly developed, its margin blunt and not everted upwards; NSL 10–11 and NIL 10–12, mental large and triangular, 5–7 scales bordering mental; 4 or 5 rows of long and narrow scales parallel to infralabials; gular pouch absent, gular fold present, rudimentary nuchal crest. Vertebrals slightly enlarged, keeled and obliquely towards the midline on sacrum, arranged in 10–12 longitudinal rows; dorsals small and keeled, scattered with large and conic scales; skin of lateral sides wrinkly, forming dorsolateral fold; ventral scales all smooth, or weakly keeled, slightly larger than vertebrals; NM 196–228; NV 114–128. Limbs stout; the

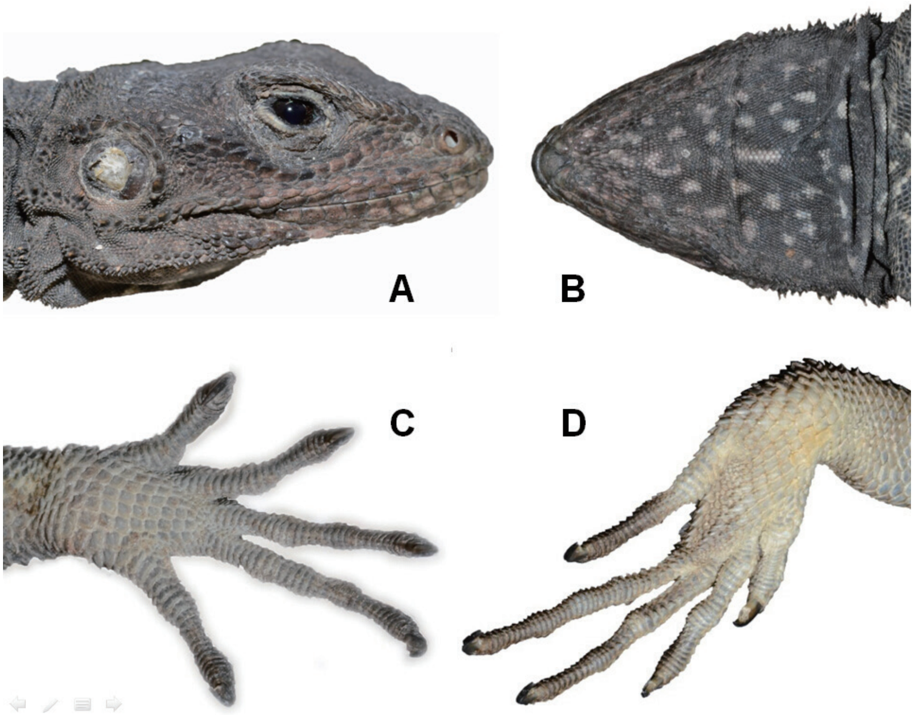

Figure 3 Head (A, B), fingers (C) and toes (D) of the female *Laudakia papenfussi*. Photos by Dahu ZOU.

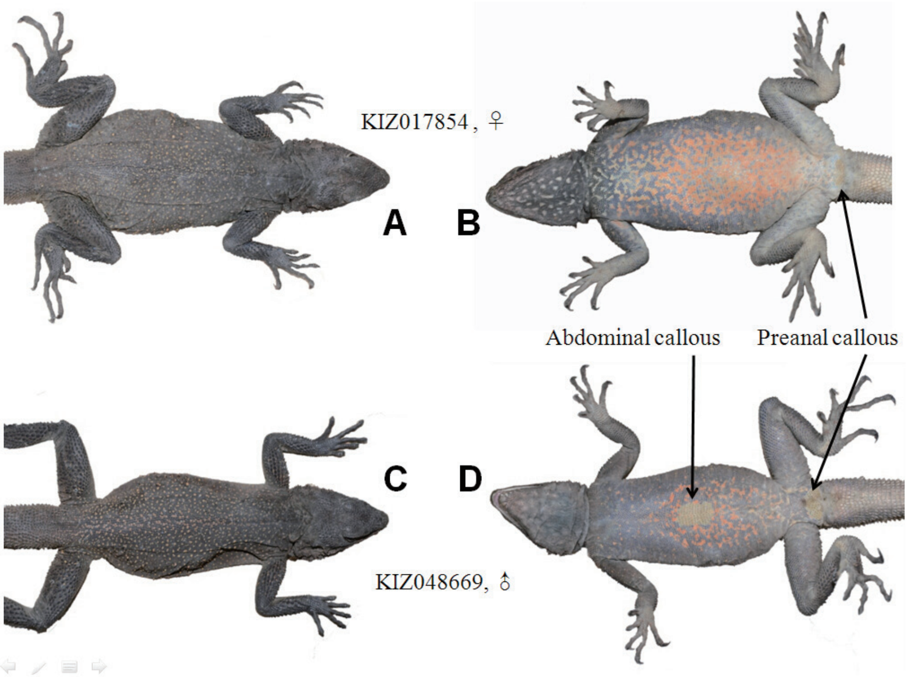

Figure 4 Dorsal and ventral views of female (A, B) and male (C, D) *Laudakia papenfussi*, showing the abdominal (only male) and preanal (both sexes) callous.

longest toe of hind limb reaches the tympanum; dorsal side of limbs covered with large and strongly keeled scales; scales of ventral side of upper arm small; fingers and toes well developed, claws compressed and sharp, NSF 27–31, NST 31–37; finger formula 4>3>5>2>1, toe formula 4>5>3>2>1. Tail cylindrical, slightly depressed at the base, covered with large and strongly keeled scales; scales of ventral side largest; scales arranged in rings and segments, each segment consisting of 4 rings of enlarged mucronate scales on dorsal side, with 3 on ventral side.

Both callous preanal and abdominal scales present in males, only preanal scales in females; 4–6 rows of callous scales, abdominal one forming an oval patch.

Coloration in life In adults, head is black or brownish black. Dorsum ranges from grayish-black to black with age, scattered with a series of small yellow spots composed of one keeled scale vertebrally. Laterally, yellow spots made of three to eight small keeled scales or one conical scale. Vertebral spots often form short random lines. Ventral surface speckled with orange patches. Coloration relates with age; young and juveniles may have a faded pattern with less black and more yellow. Gular region with white symmetric blotches on black ground.

The data of measurements and pholidosis of holotype (CIB775001) all fall in the ranges of newly collected specimens. Except for male abdominal callous, no significant difference in measurements, pholidosis and coloration was found between males and females.

Distribution and ecology This species is currently known only from type locality in the western Himalayas bordering India, where harsh climate dominates most of the year. It is most abundant around a small river between Mayang (3300 m a.s.l.) and Lugba (a.k.a. Luba, Diya; farm village (3050 m a.s.l.)).Lizards were observed mostly in roadside solid earthy cliffs basking or escaping and hiding in cracks. They bask in areas that offer long distances of sight. Consequently, they are far more difficult to approach than *L. sacra. Laudakia papenfussi* appears to be omnivorous because one specimen was caught with a small yellow flower in its mouth and in the lab they readily preyed on worms. The only sympatric ectothermic vertebrate with *L. papenfussi* is *Bufotes zamdaensis* (Fei *et al.*, 1999). This toad is also known only from Zanda and it was commonly encountered during our herpetofaunal surveys.

Comparisons Tail segment of *Laudakia papenfussi* consists 4 whorls dorsally or laterally, and 3 whorls on ventral side as *L. sacra*, *L. wui*, *L. tuberculata* and *L. dayana* do. In addition to the yellow spot on black color pattern, *L. papenfussi* can be also distinguished from *L. sacra* by gular pouch absent and having enlarged mucronate scales on both sides of body. By possessing more than 190 transverse mid-body scales, *L. papenfussi* can be distinguished from *L. dayana*. *Laudakia papenfussi* differs from *L. wui* by vertebrals arranged in oblique lines. *Laudakia papenfussi* differs from its most closely related species, i.e., *L. tuberculata* as follows, respectively: smaller yellow spots on back (~1 mm) vs. bigger spots (1–3 mm); brown iris vs. olive green; orange-yellow chest and belly vs. yellow.

3.2 Statistical analysis The measurements of 31 specimens (*Laudakia. sacra*, 17; *L. wui*, 5; *L. tuberculata*, 3; *L. papenfussi*, 6) were shown in Table 2. The PCA determined that the first three components explained 41.22% of the total variance. Component 1 explained 21.17% of variation, with the following 12 characters (load factor > 0.5): HL, UEW, EN, LAL, TD, ED, RW, IND, RH, FTL, EED, and MW. Component 2 explained another 13.75% of variance, with a loading (factor > 0.5) for the following 8 characters: SL, FEL, MH, NSL, SBR, HW, FL, TIL. Component 3 explained another 11.75% of variance, with a loading (factor > 0.5) for 5 characters: TIL, NSF, SBR, NM, NV. Loadings of each morphological character on the first three principal components were showed in appendix Table S1. Plots with first three components showed in Figure 5. Intriguingly, PC2 and PC3 discriminate species better than PC1. Plot from PC2 and PC3 successfully identified *L. papenfussi*, *L. tuberculate* and all individuals of *L. sacra* and *L. wui* but failed to distinguish *L. sacra* from *L. wui*. This is not surprising because qualitative traits (e.g., color pattern) distinguish *L. sacra* and *L. wui* and these data were not included in our PCA dataset. According to results of normality test in appendix Table S3, we removed NIL, NSN and SBO from our dataset. The results of homogeneity of variables examined by Levene's test are shown in appendix Table S4. *P*-value of FTL and NV were less than 0.05, thus rejecting H0 (variances homogeneity among four species). One way ANOVA test show significant difference for 9 characters at 95% significant level, and 8 characters at 99% significant level (appendix Table S2). For these 17 characters, multiple comparisons were carried out. Significant differences (*P*-value < 0.05) were observed between species: *Laudakia papenfussi* and *L. tuberculata* (HD, SL, ED, IOD, UEW, EN, RH, SBN, NM, NV); *L. papenfussi* and *L. wui* (SL, ED, IOD, MH, FEL, NSL, SBR, SBM, SBN); *Laudakia papenfussi* and *L. sacra* (SL, ED, RH, MH, FEL, NSF, NST, NSL, SBR, NV); *Laudakia tuberculata* and *L.wui* (UEW, EN, MH, FEL, NSF, NST, NSL, SBR, NM, NV), *L. tuberculata* and *L. sacra* (HD, UEW, EED, EN, MH, NSF, NST, SBR, SBN, NM, NV), *L. wui* and *L. sacra* (EED, NSL, SBN, SBM) (appendix Table S5). Results of PCA, ANOVA and post-hoc test suggested that characters, such as MH, NSF, NSL and SBR, may be potential taxonomically important characters to rock agamas.

3.3 Molecular phylogenetic analysis PCRs of *CO1* and

ND4 were successful for 14 individuals (*L. sacra*, 5; *L. wui*, 3; *L. tuberculata*, 3; *L. papenfussi*, 3). GTR+I+G and GTR+I were selected as the best fit models for *CO1* and *ND4* sequences, respectively. The genealogical tree constructed with the concatenated data united all species of *Laudakia* with strong support. The tree depicted matrilines A, B and C (Figure 6). *Laudakia stellio* from the Middle East (matriline C) rooted at the base of the tree. Matriline B was comprised of *L. caucasia* (Eichwald, 1831), *L. lehmanni* (Nikolsky, 1896), *L. stoliczkana* (Blanford, 1875) and *L. microlepis* (Blanford, 1874). They were widely distributed from the Middle East, across Central Asia, to Gobi Altai. Finally, matriline A hosted the four Tibetan rock agamas plus *L. nupta*. Our

Table 2 Measurements (mm) and pholidosis of 31 specimens used in PCA and the measurements (mm) for the holotype of *L. papenfussi* (CIB775001, Zhao, 1998b).

Feature	*L. tuberculata*		*L. wui*		*L. sacra*		*L. papenfussi*		
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Holotype
SVL	56.82–103.28	81.76±20.49	64.01–165.27	114.194±30.26	53.09–143.3	105.52±25.68	100.62–126.3	118.86±10.59	124
TL	101.79–148.75	118.75±19.31	116.62–286.1	186.50±53.49	102.74–259.22	176.41±42.61	215.46–254.54	232.14±14.03	193 [a]
TRL	28.57–48.28	38.46±8.42	31.17–65.70	53.71±11.67	27.56–73.82	53.55±13.77	55.76–63.51	59.79±3.46	-
LS	13.06–29.7	20.84±6.32	13.54–36.07	26.86±7.12	12.82–42.39	27.54±8.22	25.1–30.62	28.34±2.49	
HL	15.5–26.33	21.09±4.53	15.96–33.93	26.45±5.84	14.42–34.81	25.34±5.63	26.76–30.84	29.03±1.77	32 [b]
HW	12.52–22.9	17.73±4.06	12.96–33.24	23.66±6.70	12.01–38.14	23.40±6.74	21.82–29.81	26.43±3.45	24
HD	7.92–14.29	10.85±2.82	8.4–18.91	14.59±3.67	6.77–20.38	13.05±3.63	11.46–15.6	14.07±1.74	-
SL	6.41–11.16	9.22±1.94	6.9–13.87	11.77±2.58	6.14–14.97	10.87±2.66	3.76–4.57	4.03±0.32	-
ED	3.93–6.05	4.71±0.80	4.51–6.53	5.63±0.71	3.61–7.03	5.66±0.93	4.65–5.72	5.34±0.41	-
TD	2.36–4.16	3.11±0.71	2.48–5.68	4.12±1.08	2.16–5.39	3.84±0.80	3.61–4.48	4.08±0.32	-
IND	3.05–4.93	4.05±0.89	3.3–6.71	5.5±1.16	2.74–6.91	5.23±1.06	5.55–6.17	5.94±0.30	-
IOD	1.83–3.79	2.90±0.78	1.67–6.06	3.82±1.29	1.63–5.54	3.33±0.93	2.92–3.88	3.37±0.41	-
UEW	3.5–5.39	4.49±0.70	3.29–7.19	5.15±1.13	3.31–7.33	5.01±1.03	5.38–6.51	5.94±0.46	-
EED	4.77–7.9	6.46±1.30	5.07–11.74	8.92±2.39	3.65–11.4	7.46±1.93	7.34–9.75	8.74±0.99	-
EN	4.88–7.77	6.47±1.24	4.98–9.22	7.931±1.47	4.27–9.96	7.53±1.63	7.93–8.58	8.33±0.29	-
RW	2.19–4.24	3.23±0.77	2.6–5.03	4.09±0.88	2.13–4.74	3.62±0.80	3.75–5.04	4.47±0.44	-
RH	1.05–1.82	1.41±0.245	1.03–2.44	1.86±0.48	1.03–2.51	1.74±0.40	1.48–1.9	1.69±0.17	-
MW	1.85–3.93	2.81±0.75	1.99–4.36	3.41±0.81	2.05–4.57	3.19±0.63	3.37–4.05	3.76±0.28	-
MH	1.46–3.19	2.15±0.57	1.06–3.39	2.26±0.70	1.27–3.84	2.22±0.68	2.91–3.39	3.23±0.19	-
FL	11.78–21.89	16.97±4.33	13.51–28.02	22.69±4.97	10.72–31.17	22.21±5.69	23–27.6	25.90±1.63	-
LAL	20.22–33.75	27.43±5.66	20.16–46.39	34.62±9.44	17.2–48.11	35.54±8.25	36.5–42.12	39.85±2.19	-
HAL	12.01–18.55	15.52±2.79	7.31–26.86	19.84±6.50	10.21–28.05	20.33±4.64	19.84–23.65	22.12±1.43	-
FEL	14.9–27.81	22.23±5.47	16.18–35.81	27.68±6.44	12.89–35.94	27.09±6.59	29.66–35.35	33.12±2.06	-
TIL	12.82–21.69	17.91±3.67	16.08–33.35	26.52±6.04	11.94–34.73	25.43±6.44	26.29–32	30.40±2.22	-
FTL	19.58–30.8	25.46±4.16	20.87–41.16	33.49±7.00	16.28–39.6	30.41±6.54	29.95–37.31	34.99±2.73	-
NSF	21–26	24±1.63	25–3	26.80±2.04	22–30	26±1.78	27–31	28.5±1.64	-
NST	26–31	28±1.53	3–38	33.60±2.99	29–35	31.68±1.56	31–37	34.33±2.34	-
NSL	11–12	11.43±0.54	8–9	8.6±0.52	8–11	9.68±0.86	10–12	11±0.63	10
NIL	1–11	10.86±0.38	9–11	9.9±0.74	9–12	10.04±0.84	10–12	10.67±0.82	11
SBR	11–12	11.71±0.49	7–11	9±1.16	5–11	7.96±1.43	9–11	10.17±0.75	-
NSN	2–2	2±0	1–3	2.0±0.667	1–12	2.39±1.97	1–1	1±0	-
SBM	5–8	6.29±1.113	6–8	7.10±0.74	3–8	6.04±1.20	5–7	6.17±0.75	-
SBN	8–9	8.57±0.56	8–11	9.50±1.08	5–8	5.96±0.79	6–7	6.83±0.41	-
SBO	5–5	5±0	3–7	4.60±0.70	3–7	4.39±1.31	4–4	4±0	-
RV	11–13	11.86±0.69	9–12	10.80±1.03	1–20	11.61±1.91	10–11	10.67±0.52	-
NM	152–202	11.86±0.69	168–238	210.44±23.81	188–244	218.74±15.4	196–228	213.67±11.83	-
NV	94–119	175.71±16.87	116–144	128.4±8.61	112–152	133.78±10.5	114–128	117.67±5.16	-

[a] Tail of holotype is regenerated; [b] HL is interpreted as distance from snout to posterior edge of tympanum in this study.

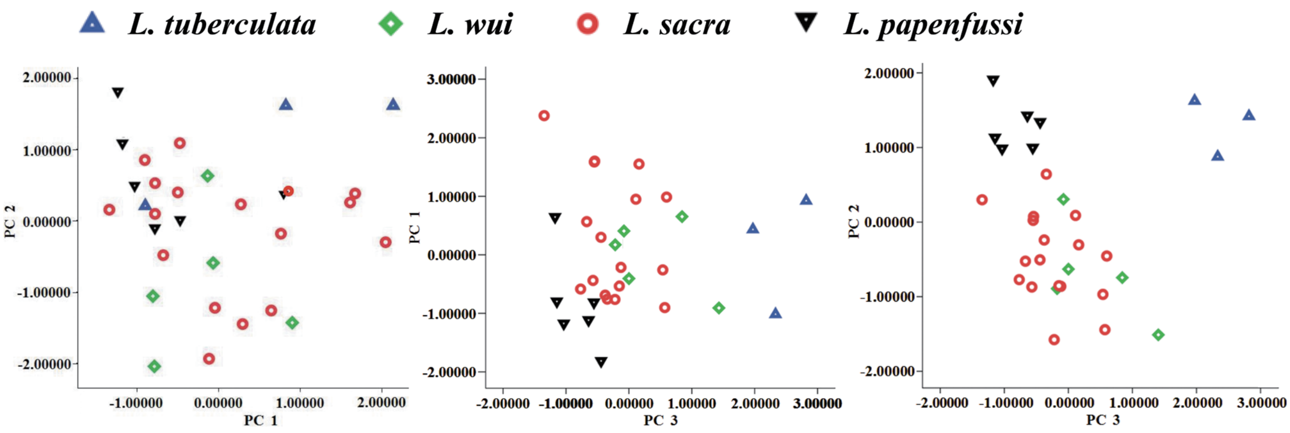

Figure 5 Principal components analysis (PCA) toward 31 individuals of *Laudakia* corresponding to *L. sacra*, *L. wui*, and *L. tuberculata*, *L. papenfussi* with 33 morphometric variables.

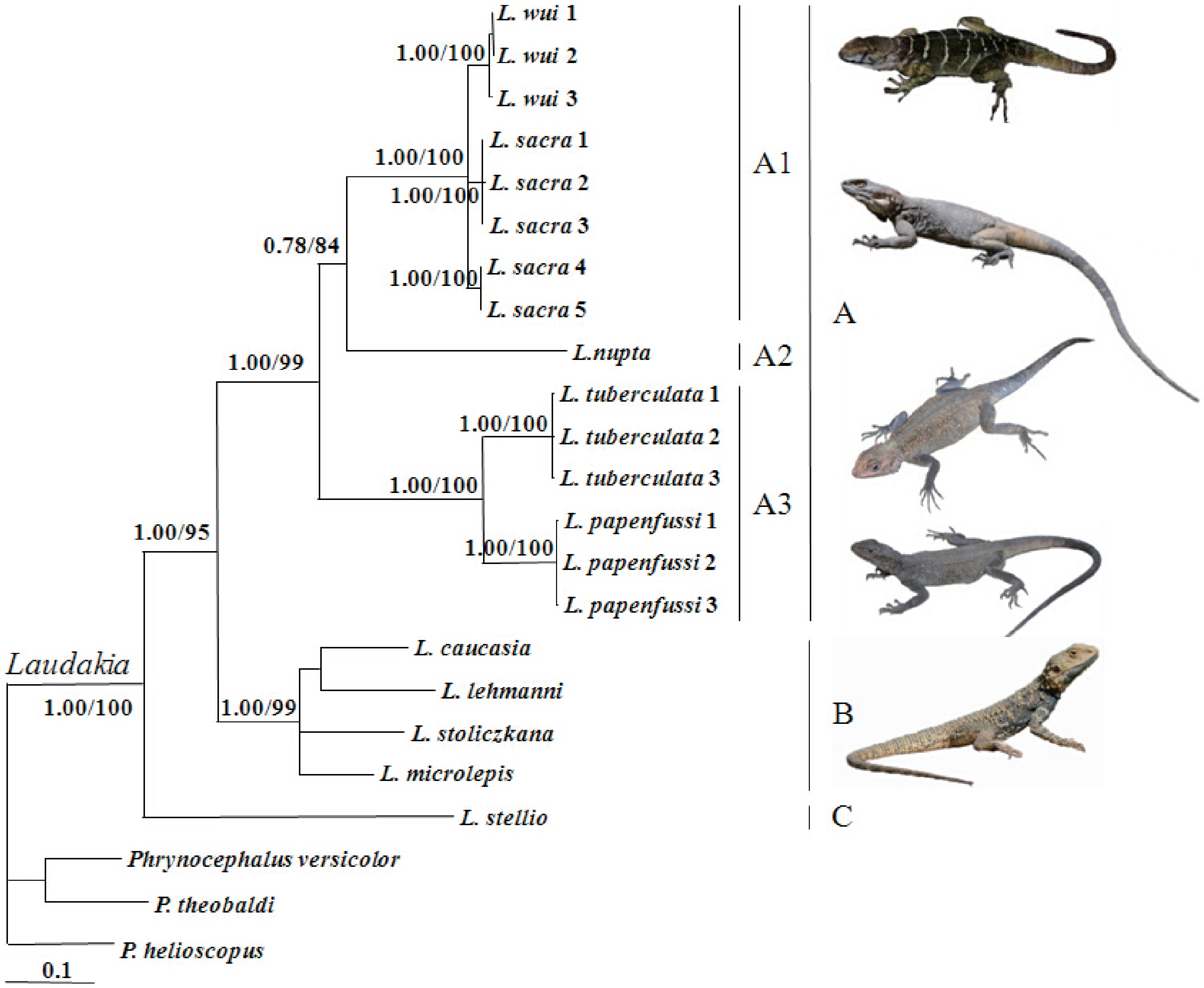

Figure 6 Bayesian tree for species of *Laudakia* inferred using concatenated mitochondrial DNA *CO1* and *ND4* sequences. Number near nodes are the Bayesian posterior probabilities (BPP) and maximum likelihood bootstrap values. Photos beside the tree are *L. wui*, *L. sacra*, *L .tuberculata*, *L. papenfussi* and *L. lehmanni* from top to bottom.

genealogy corresponded to previous assessments (Baig *et al.*, 2012; Pyron *et al.*, 2013). *Laudakia papenfussi* and *L. tuberculata*, which occur on the south slope of the Himalayas, clustered together forming the Himalaya group (matriline A3). With a distribution along Yarlung Zangbo Jiang (Brahmaputra River), *L. sacra* and *L. wui* formed matriline A1. Within this group, *L. sacra* occupies the upper and midstream reaches of the Yarlung Zangbo Jiang from Xigazê to Nyingchi while *L. wui* is located in downstream areas. Two snow covered mountains separate these two species, Namjagbarwa and Gyala Peri, that might be the geographical barrier for divergence of this two species (Zhao *et al.*, 1999). However, the morphologically identified *L. sacra* could not be clustered as a monophyletic clade based on mitochondrial DNA data. This suggested that population from Mainling, Nyingtri in Tibet might be a cryptical species, which need further investigation using nuclear data.

Conservation status The conservation status of *L. papenfussi* has not been assessed. Under IUCN assessment criteria (IUCN, 2012), there is only one area of occurrence for *L. papenfussi* (B1a), which encompasses 33 km^2 of which the species occupies about 15 km^2. Moreover, this area is extremely vulnerable to disasters, such as debris flow, landslides and severe weather (B1b (i, ii, iii)). Interpreting these data using IUCN criteria, *L. papenfussi* should be considered Critically Endangered (CR Red List category, B1ab (i, ii, iii)).

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Table S1 Loadings of each morphological character on the first three principal components.

	Component		
	1	2	3
HL	0.846		
HW		0.556	
HD	0.372		–0.317
SL	0.368	–0.823	
ED	0.646	–0.464	
TD	0.694		
IND	0.578		0.462
IOD	0.303		
UEW	0.812		
EED	0.544		
EN	0.801		
RW	0.606		
RH	0.567	–0.303	
MW	0.503		
MH	0.31	0.656	–0.346
FL		0.517	0.466
LAL	0.737		0.416
HAL	0.49	–3.23	0.395
FEL	0.399	0.726	
TIL		0.503	0.73
FTL	0.553		
NSF		0.411	0.537
NST	–3.23		0.483
NSL		0.614	–0.303
NIL			–0.491
SBR		0.582	–0.516
NSN		–0.442	
SBM			
SBN			–0.319
SBO			
RV	0.362		0.338
NM	–0.406		0.64
NV	–0.341		0.515

Table S2 Analysis of variance (ANOVA) at one way.

		Sum of Squares	*df*	Mean Square	*F*	Significance
HL	Between Groups	0.001	3	0	2.154	0.117
	Within Groups	0.003	27	0		
	Total	0.004	30			
HW	Between Groups	0.001	3	0	0.951	0.43
	Within Groups	0.008	27	0		
	Total	0.009	30			
HD	Between Groups	0.001	3	0	3.053	0.045
	Within Groups	0.002	27	0		
	Total	0.003	30			
SL	Between Groups	0.024	3	0.008	29.861	0
	Within Groups	0.007	27	0		
	Total	0.032	30			
ED	Between Groups	0.001	3	0	3.671	0.024
	Within Groups	0.002	27	0		
	Total	0.003	30			
TD	Between Groups	0	3	0	1.317	0.289
	Within Groups	0	27	0		
	Total	0	30			
IND	Between Groups	0	3	0	0.251	0.86
	Within Groups	0	27	0		
	Total	0	30			
IOD	Between Groups	0	3	0	3.061	0.045
	Within Groups	0	27	0		
	Total	0	30			
UEW	Between Groups	0	3	0	4.418	0.012
	Within Groups	0.001	27	0		
	Total	0.001	30			
EED	Between Groups	0	3	0	3.614	0.026
	Within Groups	0.001	27	0		
	Total	0.001	30			
EN	Between Groups	0	3	0	3.676	0.024
	Within Groups	0.001	27	0		
	Total	0.001	30			
RW	Between Groups	0	3	0	1.017	0.4
	Within Groups	0	27	0		
	Total	0	30			
RH	Between Groups	0	3	0	3.138	0.042
	Within Groups	0	27	0		
	Total	0	30			
MW	Between Groups	0	3	0	1.114	0.361
	Within Groups	0	27	0		
	Total	0	30			
MH	Between Groups	0	3	0	13.362	0
	Within Groups	0	27	0		
	Total	0.001	30			
FL	Between Groups	0	3	0	1.25	0.311
	Within Groups	0.003	27	0		
	Total	0.003	30			
LAL	Between Groups	0.001	3	0	0.6	0.621
	Within Groups	0.008	27	0		
	Total	0.009	30			
HAL	Between Groups	0.001	3	0	1.898	0.154
	Within Groups	0.003	27	0		
	Total	0.004	30			
FEL	Between Groups	0.003	3	0.001	9.538	0
	Within Groups	0.003	27	0		
	Total	0.006	30			
TIL	Between Groups	0.002	3	0.001	6.216	0.002
	Within Groups	0.003	27	0		
	Total	0.006	30			

Continued Table S2

		Sum of Squares	*df*	Mean Square	*F*	Significance
FTL	Between Groups	0.015	3	0.005	2.61	0.072
	Within Groups	0.05	27	0.002		
	Total	0.065	30			
NSF	Between Groups	46.968	3	15.656	6.904	0.001
	Within Groups	61.225	27	2.268		
	Total	108.194	30			
NST	Between Groups	109.874	3	36.625	9.604	0
	Within Groups	102.965	27	3.814		
	Total	212.839	30			
NSL	Between Groups	21.934	3	7.311	11.005	0
	Within Groups	17.937	27	0.664		
	Total	39.871	30			
SBR	Between Groups	52.249	3	17.416	16.12	0
	Within Groups	29.171	27	1.08		
	Total	81.419	30			
SBM	Between Groups	10.574	3	3.525	3.284	0.036
	Within Groups	28.975	27	1.073		
	Total	39.548	30			
SBN	Between Groups	45.797	3	15.266	24.005	0
	Within Groups	17.171	27	0.636		
	Total	62.968	30			
RV	Between Groups	7.692	3	2.564	0.695	0.563
	Within Groups	99.663	27	3.691		
	Total	107.355	30			
NM	Between Groups	5119.483	3	1706.494	6.265	0.002
	Within Groups	7354.259	27	272.38		
	Total	12473.742	30			
NV	Between Groups	2609.203	3	869.734	9.713	0
	Within Groups	2417.765	27	89.547		
	Total	5026.968	30			

The mean difference is significant at the 0.05 level.

Table S3 Test of Normality using One-Sample Kolmogorov-Smirnov Test.

	Asympotic Significance (2-tailed)			
	L. tuberculata (*N*=3)	*L. wui* (*N*=5)	*L. sacra* (*N*=17)	*L. papenfussi* (*N*=6)
HL	0.997	0.997	0.707	0.693
HW	0.997	0.996	0.615	0.79
HD	0.989	0.958	0.976	0.554
SL	0.999	0.864	0.069	0.999
ED	0.994	0.764	0.401	0.632
TD	0.998	0.874	0.845	0.827
IND	0.97	0.986	0.636	0.477
IOD	0.96	0.985	0.542	0.729
UEW	0.793	0.938	0.907	0.811
EED	0.898	0.794	0.752	0.747
EN	0.986	0.994	0.566	0.651
RW	0.92	0.953	0.803	0.844
RH	0.999	0.967	0.755	0.745
MW	0.946	0.71	0.544	0.781
MH	0.957	0.979	0.684	0.961
FL	0.923	0.922	0.793	0.958
LAL	0.925	0.926	0.883	0.907
HAL	0.998	0.631	0.963	0.999
FEL	0.986	0.919	0.8	0.996
TIL	0.988	0.513	0.559	0.995
FTL	0.938	0.939	0.812	0.952
NSF	0.766	0.933	0.213	0.709
NST	0.766	0.997	0.551	0.739
NSL	0.766	0.214	0.14	0.518
NIL		0.759	0.051	0.682
SBR	0.766	0.941	0.053	0.833
NSN		0.953	0.010*	
SBM	1	0.51	0.532	0.833
SBN	0.766	0.941	0.11	0.11
SBO		0.953	0.023*	
RV	1	0.967	0.156	0.272
NM	1	0.996	0.888	0.927
NV	0.96	0.805	0.653	0.337

* The mean difference is significant at the 0.05 level.

Table S4 Test of Homogeneity of Variances

	Levene Statistic	*df*1	*df*2	Significance
HL	0.416	3	27	0.743
HW	0.821	3	27	0.494
HD	0.41	3	27	0.747
SL	1.861	3	27	0.16
ED	2.615	3	27	0.072
TD	0.83	3	27	0.489
IND	2.759	3	27	0.062
IOD	0.985	3	27	0.415
UEW	2.263	3	27	0.104
EED	0.459	3	27	0.713
EN	3.271	3	27	0.036
RW	1.776	3	27	0.176
RH	2.613	3	27	0.072
MW	0.672	3	27	0.577
MH	1.358	3	27	0.277
FL	0.714	3	27	0.552
LAL	0.854	3	27	0.477
HAL	0.799	3	27	0.505
FEL	0.033	3	27	0.992
TIL	0.463	3	27	0.711
FTL	32.713	3	27	0[*]
NSF	1.344	3	27	0.281
NST	2.236	3	27	0.107
NSL	1.307	3	27	0.292
SBR	0.34	3	27	0.797
SBM	0.775	3	27	0.518
SBN	1.565	3	27	0.221
RV	0.764	3	27	0.524
NM	1.279	3	27	0.301
NV	3.353	3	27	0.034[*]

[*] The mean difference is significant at the 0.05 level.

Table S5 Post Hoc Multiple Comparisons.

Dependent Variable		(I) LABLE	(J) LABLE	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
HD	LSD	1	2	0.004825652643467	0.006646774402192	0.474	-8.81240191110905E-3	1.84637071980434E-2
			3	0.012716647967213*	0.005699562028687	0.034	1.02211266618222E-3	2.44111832682439E-2
			4	0.016090612619973*	0.006435711641422	0.019	2.88562307883746E-3	2.92956021611084E-2
		2	1	-4.825652643467154E-3	0.006646774402192	0.474	-1.84637071980434E-2	8.81240191110905E-3
			3	0.007890995323746	0.004630346081066	0.100	-1.60969006724865E-3	1.73916807147405E-2
			4	0.011264959976506	0.005511214189552	0.051	-4.31174804759326E-5	2.25730374334875E-2
		3	1	-1.271664796721306E-2*	0.005699562028687	0.034	-2.44111832682439E-2	-1.02211266618222E-3
			2	-7.890995323745903E-3	0.004630346081066	0.100	-1.73916807147405E-2	1.60969006724865E-3
			4	0.003373964652760	0.004321906894918	0.442	-5.49385580361821E-3	1.22417851091379E-2
		4	1	-1.609061261997292E-2*	0.006435711641422	0.019	-2.92956021611084E-2	-2.88562307883746E-3
			2	-1.126495997650577E-2	0.005511214189552	0.051	-2.25730374334875E-2	4.31174804759326E-5
			3	-3.373964652759867E-3	0.004321906894918	0.442	-1.22417851091379E-2	5.49385580361821E-3
SL	LSD	1	2	0.005483310915330	0.012038909596631	0.652	-1.92184911801828E-2	3.01851130108433E-2
			3	0.011668858009809	0.010323279812404	0.268	-9.51276253944512E-3	3.28504785590624E-2
			4	0.079339039653181*	0.011656624093562	0	5.54216226188729E-2	1.03256456687490E-1
		2	1	-5.483310915330220E-3	0.012038909596631	0.652	-3.01851130108433E-2	1.92184911801828E-2
			3	0.006185547094478	0.008386672165777	0.467	-1.10224827869780E-2	2.33935769759348E-2
			4	0.073855728737851*	0.009982136504259	0	5.33740764387432E-2	9.43373810369589E-2
		3	1	-1.166885800980862E-2	0.010323279812404	0.268	-3.28504785590624E-2	9.51276253944512E-3
			2	-6.185547094478397E-3	0.008386672165777	0.467	-2.33935769759348E-2	1.10224827869780E-2
			4	0.067670181643373*	0.007828014499155	0	5.16084226105573E-2	8.37319406761880E-2
		4	1	-7.933903965318127E-2*	0.011656624093562	0	-1.03256456687490E-1	-5.54216226188729E-2
			2	-7.385572873785105E-2*	0.009982136504259	0	-9.43373810369589E-2	-5.33740764387432E-2
			3	-6.767018164337266E-2*	0.007828014499155	0	-8.37319406761880E-2	-5.16084226105573E-2
ED	LSD	1	2	0.004060701780278	0.006177661262826	0.517	-8.61481211926570E-3	1.67362156798222E-2
			3	0.004523849677132	0.005297300830322	0.401	-6.34531382149744E-3	1.53930131757624E-2
			4	0.016218163171011*	0.005981494797359	0.012	3.94514961162286E-3	2.84911767304000E-2
		2	1	-4.060701780278224E-3	0.006177661262826	0.517	-1.67362156798222E-2	8.61481211926570E-3
			3	0.000463147896854	0.004303547538645	0.915	-8.36700227205942E-3	9.29329806576798E-3
			4	0.012157461390733*	0.005122246122677	0.025	1.64748048330275E-3	2.26674422981637E-2
		3	1	-4.523849677132499E-3	0.005297300830322	0.401	-1.53930131757624E-2	6.34531382149744E-3
			2	-4.631478968542754E-4	0.004303547538645	0.915	-9.29329806576798E-3	8.36700227205942E-3
			4	0.011694313493879*	0.004016877238600	0.007	3.45236219476469E-3	1.99362647929932E-2
		4	1	-1.621816317101143E-2*	0.005981494797359	0.012	-2.84911767304000E-2	-3.94514961162286E-3
			2	-1.215746139073320E-2*	0.005122246122677	0.025	-2.26674422981637E-2	-1.64748048330275E-3
			3	-1.169431349387893E-2*	0.004016877238600	0.007	-1.99362647929932E-2	-3.45236219476469E-3
IOD	LSD	1	2	0.002351358794335	0.002433467147510	0.342	-2.64170335977845E-3	7.34442094844889E-3
			3	0.003386442026004	0.002086680863944	0.116	-8.95073448791454E-4	7.66795750079957E-3
			4	0.006620062919852*	0.002356194433963	0.009	1.78555127748661E-3	1.14545745622170E-2
		2	1	-2.351358794335220E-3	0.002433467147510	0.342	-7.34442094844889E-3	2.64170335977845E-3
			3	0.001035083231669	0.001695227547690	0.547	-2.44323638305935E-3	4.51340284639703E-3
			4	0.004268704125517*	0.002017724366987	0.044	1.28675695486900E-4	8.40873255554627E-3
		3	1	-3.386442026004056E-3	0.002086680863944	0.116	-7.66795750079957E-3	8.95073448791454E-4
			2	-1.035083231668836E-3	0.001695227547690	0.547	-4.51340284639703E-3	2.44323638305935E-3
			4	0.003233620893848	0.001582304108277	0.051	-1.29989618676109E-5	6.48024074956311E-3
		4	1	-6.620062919851805E-3*	0.002356194433963	0.009	-1.14545745622170E-2	-1.78555127748661E-3
			2	-4.268704125516585E-3*	0.002017724366987	0.044	-8.40873255554627E-3	-1.28675695486900E-4
			3	-3.233620893847749E-3	0.001582304108277	0.051	-6.48024074956311E-3	1.29989618676109E-5
UEW	LSD	1	2	0.012470574493814*	0.003954003095615	0.004	4.35763027997306E-3	2.05835187076541E-2
			3	0.011929602016615*	0.003390529682736	0.002	4.97280974654610E-3	1.88863942866836E-2
			4	0.011507910105614*	0.003828447035043	0.006	3.65258564838579E-3	1.93632345628429E-2
		2	1	-1.247057449381358E-2*	0.003954003095615	0.004	-2.05835187076541E-2	-4.35763027997306E-3
			3	-5.409724771987257E-4	0.002754479335460	0.846	-6.19269723471004E-3	5.11075228031259E-3
			4	-9.626643881992525E-4	0.003278486172015	0.771	-7.68956236379771E-3	5.76423358739921E-3
		3	1	-1.192960201661485E-2*	0.003390529682736	0.002	-1.88863942866836E-2	-4.97280974654610E-3
			2	0.000540972477199	0.002754479335460	0.846	-5.11075228031259E-3	6.19269723471004E-3
			4	-4.216919110005268E-4	0.002570996427354	0.871	-5.69694083840773E-3	4.85355701640668E-3
		4	1	-1.150791010561433E-2*	0.003828447035043	0.006	-1.93632345628429E-2	-3.65258564838579E-3
			2	0.000962664388199	0.003278486172015	0.771	-5.76423358739921E-3	7.68956236379771E-3
			3	0.000421691911001	0.002570996427354	0.871	-4.85355701640668E-3	5.69694083840773E-3

Continued Table S5

Dependent Variable		(I) LABLE	(J) LABLE	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
EED	LSD	1	2	0.001643058094871	0.004590337485484	0.723	-7.77553643878700E-3	1.10616526285287E-2
			3	0.009845959603376*	0.003936181920435	0.019	1.76958142060968E-3	1.79223377861426E-2
			4	0.006841069284443	0.004444575158687	0.135	-2.27844565894128E-3	1.59605842278272E-2
		2	1	-1.643058094870836E-3	0.004590337485484	0.723	-1.10616526285287E-2	7.77553643878700E-3
			3	0.008202901508505*	0.003197769308925	0.016	1.64162085578943E-3	1.47641821612211E-2
			4	0.005198011189572	0.003806106775113	0.183	-2.61147484058672E-3	1.30074972197310E-2
		3	1	-9.845959603376114E-3*	0.003936181920435	0.019	-1.79223377861426E-2	-1.76958142060968E-3
			2	-8.202901508505278E-3*	0.003197769308925	0.016	-1.47641821612211E-2	-1.64162085578943E-3
			4	-3.004890318933140E-3	0.002984757722779	0.323	-9.12910729883047E-3	3.11932666096419E-3
		4	1	-6.841069284442974E-3	0.004444575158687	0.135	-1.59605842278272E-2	2.27844565894128E-3
			2	-5.198011189572138E-3	0.003806106775113	0.183	-1.30074972197310E-2	2.61147484058672E-3
			3	0.003004890318933	0.002984757722779	0.323	-3.11932666096419E-3	9.12910729883047E-3
EN	LSD	1	2	0.008143809355111*	0.003293732311246	0.020	1.38562888577937E-3	1.49019898244433E-2
			3	0.007591064610566*	0.002824352156085	0.012	1.79597266742509E-3	1.33861565537068E-2
			4	0.010481473470090*	0.003189142597081	0.003	3.93789336799374E-3	1.70250535721872E-2
		2	1	-8.143809355111345E-3*	0.003293732311246	0.020	-1.49019898244433E-2	-1.38562888577937E-3
			3	-5.527447445454053E-4	0.002294514538425	0.811	-5.26069969499268E-3	4.15521020590186E-3
			4	0.002337664114979	0.002731018559069	0.400	-3.26592310559139E-3	7.94125133554967E-3
		3	1	-7.591064610565940E-3*	0.002824352156085	0.012	-1.33861565537068E-2	-1.79597266742509E-3
			2	0.000552744744545	0.002294514538425	0.811	-4.15521020590186E-3	5.26069969499268E-3
			4	0.002890408859525	0.002141671060973	0.188	-1.50393717964183E-3	7.28475489869092E-3
		4	1	-1.048147347009048E-2*	0.003189142597081	0.003	-1.70250535721872E-2	-3.93789336799374E-3
			2	-2.337664114979140E-3	0.002731018559069	0.400	-7.94125133554967E-3	3.26592310559139E-3
			3	-2.890408859524546E-3	0.002141671060973	0.188	-7.28475489869092E-3	1.50393717964183E-3
RH	LSD	1	2	0.001875433358652	0.001790378741681	0.304	-1.79812037958623E-3	5.54898709689044E-3
			3	0.001022958137059	0.001535237105338	0.511	-2.12708820570524E-3	4.17300447982325E-3
			4	0.004280622997577*	0.001733526762484	0.020	7.23719885177737E-4	7.83752610997527E-3
		2	1	-1.875433358652100E-3	0.001790378741681	0.304	-5.54898709689044E-3	1.79812037958623E-3
			3	-8.524752215930964E-4	0.001247232520398	0.500	-3.41158496809307E-3	1.70663452490688E-3
			4	0.002405189638924	0.001484503629696	0.117	-6.40760210311598E-4	5.45113948816041E-3
		3	1	-1.022958137059004E-3	0.001535237105338	0.511	-4.17300447982325E-3	2.12708820570524E-3
			2	0.000852475221593	0.001247232520398	0.500	-1.70663452490688E-3	3.41158496809307E-3
			4	0.003257664860518*	0.001164151174686	0.009	8.69023954500364E-4	5.64630576653464E-3
		4	1	-4.280622997576505E-3*	0.001733526762484	0.020	-7.83752610997527E-3	-7.23719885177737E-4
			2	-2.405189638924405E-3	0.001484503629696	0.117	-5.45113948816041E-3	6.40760210311598E-4
			3	-3.257664860517501E-3*	0.001164151174686	0.009	-5.64630576653464E-3	-8.69023954500364E-4
MH	LSD	1	2	0.011226001826698*	0.002450919013334	0	6.19713140171872E-3	1.62548722516783E-2
			3	0.009279989302787*	0.002101645715428	0	4.96776848904189E-3	1.35922101165323E-2
			4	0.002333456036948	0.002373092130386	0.334	-2.53572681459761E-3	7.20263888849325E-3
		2	1	-1.122600182669850E-2*	0.002450919013334	0	-1.62548722516783E-2	-6.19713140171872E-3
			3	-1.946012523911411E-3	0.001707385050508	0.264	-5.44927727392507E-3	1.55725222610224E-3
			4	-8.892545789750683E-3*	0.002032194689694	0	-1.30622648694939E-2	-4.72282671000742E-3
		3	1	-9.279989302787090E-3*	0.002101645715428	0	-1.35922101165323E-2	-4.96776848904189E-3
			2	0.001946012523911	0.001707385050508	0.264	-1.55725222610224E-3	5.44927727392507E-3
			4	-6.946533265839272E-3*	0.001593651768762	0	-1.02164365976269E-2	-3.67662993405162E-3
		4	1	-2.333456036947817E-3	0.002373092130386	0.334	-7.20263888849325E-3	2.53572681459761E-3
			2	0.008892545789751*	0.002032194689694	0	4.72282671000742E-3	1.30622648694939E-2
			3	0.006946533265839*	0.001593651768762	0	3.67662993405162E-3	1.02164365976269E-2
FEL	LSD	1	2	0.023551702535160*	0.007804630128598	0.006	0.00753792426746	0.03956548080286
			3	0.013097396456962	0.006692415123076	0.061	-6.34305121517300E-4	0.02682909803544
			4	-7.772839633039985E-3	0.007556800627842	0.313	-2.32781137682020E-2	0.00773243450212
		2	1	-2.355170253515962E-2*	0.007804630128598	0.006	-3.95654808028564E-2	-7.53792426746280E-3
			3	-1.045430607819761E-2	0.005436943747963	0.065	-2.16099931766542E-2	0.00070138102026
			4	-3.132454216819960E-2*	0.006471257441015	0	-4.46024656656741E-2	-1.80466186707251E-2
		3	1	-1.309739645696201E-2	0.006692415123076	0.061	-2.68290980354413E-2	0.00063430512152
			2	0.010454306078198	0.005436943747963	0.065	-7.01381020259002E-4	0.02160999317665
			4	-2.087023609000199E-2*	0.005074775029817	0	-3.12828143604515E-2	-1.04576578195525E-2
		4	1	0.007772839633040	0.007556800627842	0.313	-7.73243450212203E-3	0.02327811376820
			2	0.031324542168200*	0.006471257441015	0	0.01804661867073	0.04460246566567
			3	0.020870236090002*	0.005074775029817	0	0.01045765781955	0.03128281436045

Continued Table S5

Dependent Variable		(I) LABLE	(J) LABLE	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
NSF	LSD	1	2	-3.333*	1.100	0.005	-5.59	-1.08
			3	-3.098*	0.943	0.003	-5.03	-1.16
			4	-4.833*	1.065	0	-7.02	-2.65
		2	1	3.333*	1.100	0.005	1.08	5.59
			3	0.235	0.766	0.761	-1.34	1.81
			4	-1.500	0.912	0.112	-3.37	0.37
		3	1	3.098*	0.943	0.003	1.16	5.03
			2	-0.235	0.766	0.761	-1.81	1.34
			4	-1.735*	0.715	0.022	-3.20	-0.27
		4	1	4.833*	1.065	0	2.65	7.02
			2	1.500	0.912	0.112	-0.37	3.37
			3	1.735*	0.715	0.022	0.27	3.20
NST	LSD	1	2	-6.267*	1.426	0	-9.19	-3.34
			3	-4.549*	1.223	0.001	-7.06	-2.04
			4	-7.000*	1.381	0	-9.83	-4.17
		2	1	6.267*	1.426	0	3.34	9.19
			3	1.718	0.993	0.095	-0.32	3.76
			4	-0.733	1.182	0.540	-3.16	1.69
		3	1	4.549*	1.223	0.001	2.04	7.06
			2	-1.718	0.993	0.095	-3.76	0.32
			4	-2.451*	0.927	0.014	-4.35	-0.55
		4	1	7.000*	1.381	0	4.17	9.83
			2	0.733	1.182	0.540	-1.69	3.16
			3	2.451*	0.927	0.014	0.55	4.35
NSL	LSD	1	2	2.867*	0.595	0	1.65	4.09
			3	1.843*	0.510	0.001	0.80	2.89
			4	0.667	0.576	0.258	-0.52	1.85
		2	1	-2.867*	0.595	0	-4.09	-1.65
			3	-1.024*	0.415	0.020	-1.87	-0.17
			4	-2.200*	0.494	0	-3.21	-1.19
		3	1	-1.843*	0.510	0.001	-2.89	-0.80
			2	1.024*	0.415	0.020	0.17	1.87
			4	-1.176*	0.387	0.005	-1.97	-0.38
		4	1	-0.667	0.576	0.258	-1.85	0.52
			2	2.200*	0.494	0	1.19	3.21
			3	1.176*	0.387	0.005	0.38	1.97
SBR	LSD	1	2	3.067*	0.759	0	1.51	4.62
			3	3.843*	0.651	0	2.51	5.18
			4	1.500	0.735	0.051	0	3.01
		2	1	-3.067*	0.759	0	-4.62	-1.51
			3	0.776	0.529	0.154	-0.31	1.86
			4	-1.567*	0.629	0.019	-2.86	-0.28
		3	1	-3.843*	0.651	0	-5.18	-2.51
			2	-0.776	0.529	0.154	-1.86	0.31
			4	-2.343*	0.494	0	-3.36	-1.33
		4	1	-1.500	0.735	0.051	-3.01	0.01
			2	1.567*	0.629	0.019	0.28	2.86
			3	2.343*	0.494	0	1.33	3.36
SBM	LSD	1	2	-0.600	0.757	0.435	-2.15	0.95
			3	0.941	0.649	0.158	-0.39	2.27
			4	0.833	0.733	0.265	-0.67	2.34
		2	1	0.600	0.757	0.435	-0.95	2.15
			3	1.541*	0.527	0.007	0.46	2.62
			4	1.433*	0.627	0.030	0.15	2.72
		3	1	-0.941	0.649	0.158	-2.27	0.39
			2	-1.541*	0.527	0.007	-2.62	-0.46
			4	-0.108	0.492	0.828	-1.12	0.90
		4	1	-0.833	0.733	0.265	-2.34	0.67
			2	-1.433*	0.627	0.030	-2.72	-0.15
			3	0.108	0.492	0.828	-0.90	1.12

Continued Table S5

Dependent Variable		(I) LABLE	(J) LABLE	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
							Lower Bound	Upper Bound
SBN	LSD	1	2	-1.067	0.582	0.078	-2.26	0.13
			3	2.157*	0.499	0	1.13	3.18
			4	1.500*	0.564	0.013	0.34	2.66
		2	1	1.067	0.582	0.078	-0.13	2.26
			3	3.224*	0.406	0	2.39	4.06
			4	2.567*	0.483	0	1.58	3.56
		3	1	-2.157*	0.499	0	-3.18	-1.13
			2	-3.224*	0.406	0	-4.06	-2.39
			4	-0.657	0.379	0.094	-1.43	0.12
		4	1	-1.500*	0.564	0.013	-2.66	-0.34
			2	-2.567*	0.483	0	-3.56	-1.58
			3	0.657	0.379	0.094	-0.12	1.43
NM	LSD	1	2	-30.933*	12.053	0.016	-55.66	-6.20
			3	-43.569*	10.335	0	-64.77	-22.36
			4	-41.000*	11.670	0.002	-64.94	-17.06
		2	1	30.933*	12.053	0.016	6.20	55.66
			3	-12.635	8.396	0.144	-29.86	4.59
			4	-10.067	9.994	0.323	-30.57	10.44
		3	1	43.569*	10.335	0	22.36	64.77
			2	12.635	8.396	0.144	-4.59	29.86
			4	2.569	7.837	0.746	-13.51	18.65
		4	1	41.000*	11.670	0.002	17.06	64.94
			2	10.067	9.994	0.323	-10.44	30.57
			3	-2.569	7.837	0.746	-18.65	13.51
NV	Dunnett T3	1	2	-20.667*	3.866	0.016	-36.13	-5.20
			3	-27.549*	2.970	0	-36.27	-18.82
			4	-11.333*	2.427	0.012	-19.82	-2.85
		2	1	20.667*	3.866	0.016	5.20	36.13
			3	-6.882	4.569	0.599	-21.87	8.10
			4	9.333	4.236	0.278	-5.78	24.45
		3	1	27.549*	2.970	0	18.82	36.27
			2	6.882	4.569	0.599	-8.10	21.87
			4	16.216*	3.438	0.001	6.20	26.23
		4	1	11.333*	2.427	0.012	2.85	19.82
			2	-9.333	4.236	0.278	-24.45	5.78
			3	-16.216*	3.438	0.001	-26.23	-6.20

* The mean difference is significant at the 0.05 level.